METHOD OF PRODUCING POLYGONAL RING-SHAPED MACHINE PARTS HAVING COMPLEX CROSS-SECTION

BACKGROUND OF THE INVENTION

Field in the Industry

The present invention concerns a method of producing a polygonal, particularly square, ring-shaped machine part having a complex cross-section from metallic material.

Prior Art

To date, when it is intended to produce a machine part such as "frame" or a sealing ring for transition piece of a gas turbine combustor as shown in Fig. 1 (plan view) and Fig. 2 (side view), which has curved profile in one or both of plan view and side view (the illustrated example is curvilinear in the plan view) and a complex cross-section such as shown in Fig. 3 from metallic material, the only practical way to carry out the production is cutting a metal plate by water jet or fusion to prepare a blank and machining the blank. In case where the metallic material is an expensive alloy like a Ni-based super alloy having high heat resistance (e.g., Hastelloy X or Nimonic 263) or a Co-based super alloy (e.g., L605), the fact that there is no method of producing other than the above method of low material yield means very high production costs of the part.

In order to solve this problem one of the inventors has developed an improved method of producing the part starting from a rod-shaped metallic material and the method was disclosed (Japanese Patent Disclosure 2003-220416). The method comprises the steps of

bending a rod having a rectangular cross-section to butt both the ends, flash butt welding the butted ends to form a ring, and forming the inside of the resulting ring by mandrel pushing out. The ring is then subjected to necessary heat treatment and finished by machining.

The improved method remarkably increased the material yield. However, there still has been a room of further improvement for decreasing the manufacturing costs. From the viewpoint of product variation, if a part of complex cross-section is to be produced, the amount of material to be removed from the blank by machining is a significant matter and the processing is disadvantageous from both the material yield and time consumption.

During practice of the above-described method it was experienced that volume decrease occurs at the parts which were processed by bending, and some countermeasure was demanded. Practical countermeasure is to use a somewhat bolder or thicker blank with calculation of probable volume decrease. However, use of a thicker blank necessitates cutting off of large amount of the material at the parts other than the parts to be bent, and gives adverse effect to the intension of the invention. The same problem is experienced in the case of, for example, an angular ring-shaped machine part, if there is a large difference between the thickness of a pair of longer sides and that of a pair of shorter sides, then the rod blanks must be prepared by taking the thicker sides as the standard.

On the other hand, there has bee known a method, as the technology of producing a flange-type machine part having a lug or lugs, which comprises the steps of preparing a stepped rod having

plural ring-shaped notches by machining a rod of round section, coiling the rod to a circle to form a ring with butted ends, welding the butted ends and pressing the welded product to flatten so as to form the above steps into lug or lugs (Japanese Patent Publication 56-1975). The inventors were hinted by this method of forming flanges with lugs and an idea occurred to them to utilize the stepped blank for producing a polygonal, ring-shaped machine part. The idea is to have the parts to be bent thicker to give excess metal so that the excess metal may compensate the volume decrease caused by the bending. The sides which are not subjected to bending may be thinner, or of an appropriate thickness without excess material, so as to increase the material yield.

In order to produce a polygonal, ring-shaped machine part starting from the stepped blank the thicker parts are bent to form a nearly polygonal shape and, like the above-mentioned method of forming the lugged flanges, the butted ends are welded. Contrarily to pressing whole the blank to flatten for producing the flange, the inventors chose die forging as the method of producing the polygonal, ring-shaped machine part having a complex cross-section. Combination of the stepped blanks and the die forging is convenient also for producing polygonal, ring-shaped machine part having different thickness of the sides, and preparation of the stepped blanks with different thickness which are appropriate for the parts to be bent, the parts of large cross-section and the parts of small cross-section followed by die forging makes it possible to carry out the processing with minimized material to be removed.

SUMMARY OF THE INVENTION

The object of the invention is to provide a method of producing polygonal, ring-shaped machine part having a complex cross-section with improved efficiency of the producing steps and remarkably increased material yield. The method is based on the inventors' knowledge developed as described above, or combination of the above-explained method of Japanese Patent Disclosure 2003-220416 as the base and the idea of using the stepped blank, which the inventors were hinted from the method of producing a flange with lugs disclosed in Japanese Patent Publication No. 56-1975.

BRIEF EXPLANATION OF THE DRAWINGS

Fig. 1 is a plan view illustrating an example of the polygonal ring-shaped part having a complex cross-section (a frame of the transition piece for a gas turbine) produced by the method according to the invention;

Fig. 2 is a side view along the allow line in Fig. 1;

Fig. 3 is an enlarged cross-section at part I-I of Fig. 1;

Fig. 4 to Fig. 7 illustrate a scheme of the basic embodiment of the method of producing a polygonal ring-shaped machine part having a complex cross-section according to the invention; wherein,

Fig. 4 shows a long notched blank having large diameter parts and small diameter parts obtained by forging;

Fig. 5 shows a polygonal, open ring-shaped first intermediate obtained by bending the large diameter parts of the long blank;

Fig. 6 shows a polygonal, closed ring-shaped second intermediate obtained by welding the butted ends of the first intermediate of Fig. 5; and

Fig. 7 shows a polygonal, ring-shaped product having a complex cross-section obtained by die forging the above closed ring-shaped second intermediate of Fig. 6; and

Fig. 8 to Fig. 11, corresponding to Fig. 4 to Fig. 7, illustrate a scheme of an alternative embodiment of the method of producing a polygonal ring-shaped machine part having a complex cross-section according to the invention; wherein,

Fig. 8 shows a short notched blank having large diameter parts and small diameter parts obtained by forging;

Fig. 9 shows an square U-shaped first intermediate obtained by bending the large diameter parts of the short blank of Fig. 8;

Fig. 10 shows a polygonal, closed ring-shaped second intermediate obtained by welding the butted ends of the two first intermediate of Fig. 9; and

Fig. 11 shows a polygonal, ring-shaped product having a complex cross-section obtained by die forging the above closed ring-shaped second intermediate of Fig. 10.

DETAILED EXPLANATION OF THE PREFERRED EMBODIMENTS

The basic method of the invention is a method of producing a polygonal, ring-shaped machine part having a complex cross-section from a metal rod and comprises the steps as illustrated in Fig. 4 to Fig. 7, which are as follows:

A_1) forging the rod material to prepare a long notched blank **1** having large diameter parts **11**, the number of which corresponds to the number of the parts to be bent, and the remaining small diameter parts **12** (Fig. 4);

B_1) bending the large diameter parts **11** of the above long blank **1**

to form a first intermediate **3** of polygonal, open ring-shape with confronting ends (Fig. 5);

C_1) butt welding the confronting ends of the above ring-shaped first intermediate **3** to form a polygonal, closed ring-shaped second intermediate **5** (Fig. 6);

D_1) die-forging the above closed ring-shaped second intermediate **5** to form a polygonal, ring-shaped product **7** having a complex cross-section (Fig. 7); and

E_1) subjecting the above polygonal, ring-shaped product **7** to necessary finishing step or steps such as machining to obtain a polygonal, ring-shaped machine part **8** having a complex cross-section.

The method according to the present invention includes, as an alternative embodiment comprising the steps of preparing two blanks of symmetric shape as the material to be welded and welding the two parts to form a ring-shaped second intermediate. In other words, the alternative method is a method of producing a polygonal, ring-shaped product having a complex cross-section from metallic rods, which comprises the steps as illustrated in Fig. 8 to Fig. 11, which are the followings:

A_2) forging the rod material to prepare two short notched blanks **2** having large diameter parts **21**, the number of which corresponds to half of the parts to be bent, and the remaining small diameter parts **22** (Fig. 8);

B_2) bending the large diameter parts **21** of the above short blanks **2** to form a first intermediate **4** of square U-shape, the number of which is half of the final product (Fig. 9);

C_2) butting the ends of the above two square U-shaped first intermediates **4** and welding the confronting ends to form a polygonal,

closed ring-shaped second intermediate **6** (Fig. 10);

D_2) die-forging the above closed ring-shaped second intermediate **6** to form a polygonal, ring-shaped product **7** having a complex cross-section (Fig. 11); and

E_2) subjecting the above polygonal, ring-shaped product **7** to necessary finishing step or steps such as machining to obtain a polygonal, ring-shaped part **8** having a complex cross-section.

The above described basic embodiment and the alternative embodiment may be chosen depending on the shape and the size of the machine part to be produced, and convenience of the devices used.

The stepped blank **1** and **2** may be of round cross-section, or square or angular cross-section, and this could be decided by taking into account the cross-section of the ring-shaped body to be produced and the process appropriate for the production. The thicker parts **11** and **21** are the parts to be the corners of the ring-shaped first intermediate **3** or the square U-shaped intermediate, and therefore, the numbers of them are, as a matter of course, in the basic embodiment, equal to the number of the parts to be bent, and in the alternative embodiment, the half of the number of the parts to be bent. In case of producing the square ring-shaped bodies, the number of the thicker parts is four or two, a half of four, as shown in Fig. 4 and Fig. 8, corresponding to the four parts to be bent.

Length of the thicker parts **11** and **21**, ratio of cross-section diameter thereof to the thinner parts **12** and **22**, and taper of the transition parts from the thicker to thinner parts may be so decided that sufficient material is given during the bending step to the parts to be bent and that neither material shortage nor excess flash occurs. As mentioned above, form and size of the thinner parts may

vary depending on the cross-section areas of various parts of the resulting polygonal, ring-shaped machine part. For example, in case of a nearly angular ring-shaped body in which the shorter sides have cross-section areas larger than those of the longer sides, preparation of the stepped blank will be carried out to form the blank of maximum diameter at the parts to be bent, the medium diameter at the shorter sides, and the minimum diameter at the longer sides. Preparation of the stepped blanks can be carried out by free forging using a rotary forging machine under high productivity. Any other means such as die forging with forging rolls may be used.

In case where the two square U-shaped blanks **3** are combined in accordance with the alternative embodiment, it is a matter of course that the blanks are of the shape, depending on the plan form of the ring-shaped machine part to be produced, which is a half of the machine part. In this case, butting of the opposite ends is preferably done in one axis. For example, in case where the ring-shaped machine part is hexagonal, the blanks are of the shape having three parts to be bent (a roof + both sides). Thus, the term "square U-shaped" in this specification may include various shapes which are possible as the half of a polygonal shape.

Welding for obtaining the ring-shaped second intermediate **5** and **6** may be carried out by any technology such as flash butt welding and MIG welding. Flash butt welding is the most preferable because of simplicity of steps and short period of time. The flash butt welding can be practiced in accordance with the known technology in this field. Flashes resulting from the welding are preferably removed prior to die forging. An appropriate means such

as abrading may be employed for this purpose.

The die forging for obtaining the polygonal, ring-shaped product having a complex cross-section 7 may also be carried out in accordance with the technology known in this field. Use of the die forging in the method is a characteristic feature of this invention, which facilitates production of various polygonal, ring-shaped machine part having a complex cross-section, in addition to the angular section with ribs as exemplified in Fig. 3, such as triangle or a waterdrop shape. After the die forging, removal of forging flashes may be done by punching.

The method of producing polygonal, ring-shaped machine part according to the invention may be practiced with step or steps other than the above basic steps, if necessary, by adding it between some of the basic steps or after the basic steps. Examples of such additional steps are mandrel pushing out, in which a tool having a taper is forced to pass in the ring intermediate to form the inside of the intermediate. This may be carried out after flash removal following to flash butt welding or, if necessary, prior to the final machining.

Ordinarily, it will be necessary to subject the product after the die forging to heat treatments such as annealing and solid solution treatment. Conditions for the heat treatment, or the temperature, the period of time and the cooling rate may be decided on the basis of the material used. For example, if the material is Nimonic 163, the above noted Ni-based super alloy, heating at 1150°C for 1 hour followed by water quenching will be suitable.

The final machining is for providing the finished product by completing the outer profile of the ring-shaped product. Sometimes

it is followed by necessary additional processing step such as drilling with a drill or an electrical discharge machine. Further, during the production process, various inspections such as dimension checking, defect detecting and determination of surface hardness may be of course practiced upon necessity.

Production of the polygonal, ring-shaped machine part having complex cross-section according to the present invention will enjoy the merit of increased material yield given by the previously proposed method, which comprises bending and welding a rod-shaped blank. The invention, by employing processing rod material to prepare stepped blank, made it possible to use of an efficient forming technology or die forging for outer shape, and succeeded to remarkably decrease the work of machining. Thus, rationalization of the process and decrease in the manufacturing costs are realized.